



## Shadowing effects of offshore wind farms - an idealised mesoscale study

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# Shadowing effects of offshore wind farms - an idealised mesoscale study

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# Wind Farm Interaction

Wind Farm (WF) interaction is already an issue (e.g.):

- Hornsrev I – Hornsrev II
- Rødsand 2 – Nysted

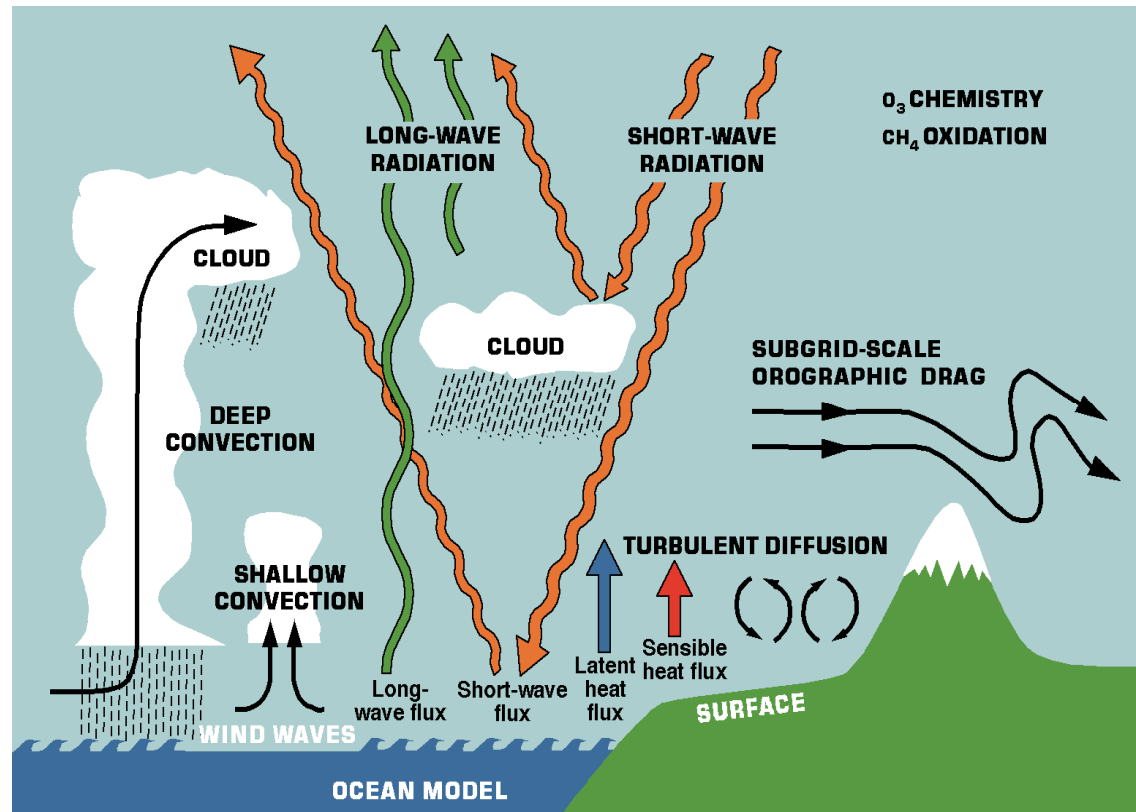
Large scale effects on the WF wake advection are not negligible anymore  
⇒ Mesoscale Models are a suitable solution.

Drawback: Single turbine wakes cannot be resolved! ( $D_0 \ll \Delta x$ )

Possible solutions:

- (1) WF from microscale model & Mesoscale model as a wake transport medium
- (2) WF “parametrised” inside mesoscale model

# Mesoscale Model



Horizontal scale:  $\Delta x \sim km$

Vertical scale:  $\Delta z \sim 10m$  (Boundary layer)

Time step:  $\leq \Delta x / |U|$

Unresolved processes to be parametrised:

Radiation

Micro physics

Vertical mixing (turbulence & convection)

... Wind turbines

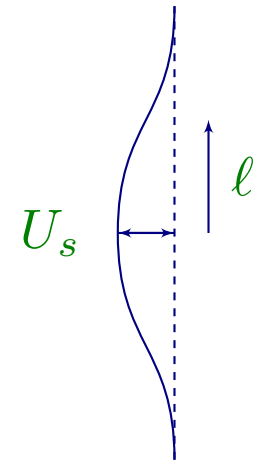
# Wind Farm Parametrisation

From the diffusion equation, one can obtain the typical length scale  $\ell$ :

$$(1) \quad \ell^2 = \frac{2K_m}{U_0}x + \ell_0^2 \quad \left\{ \begin{array}{l} K_m \text{ is the turbulence coefficient for momentum} \\ \ell_0 \text{ the initial length scale} \\ U_0 \text{ background hub-height velocity} \end{array} \right.$$

Assumption: In the far wake the ensemble average will be Gaussian. then  $U$  becomes:

$$(2) \quad \underbrace{U(z)}_{\text{Wake velocity}} = \underbrace{U_0(z)}_{\text{Upstream velocity}} - \underbrace{U_s f(z)}_{\text{Velocity deficit}} \quad \text{where } f = e^{-\frac{1}{2}\left(\frac{z}{\ell}\right)^2}.$$



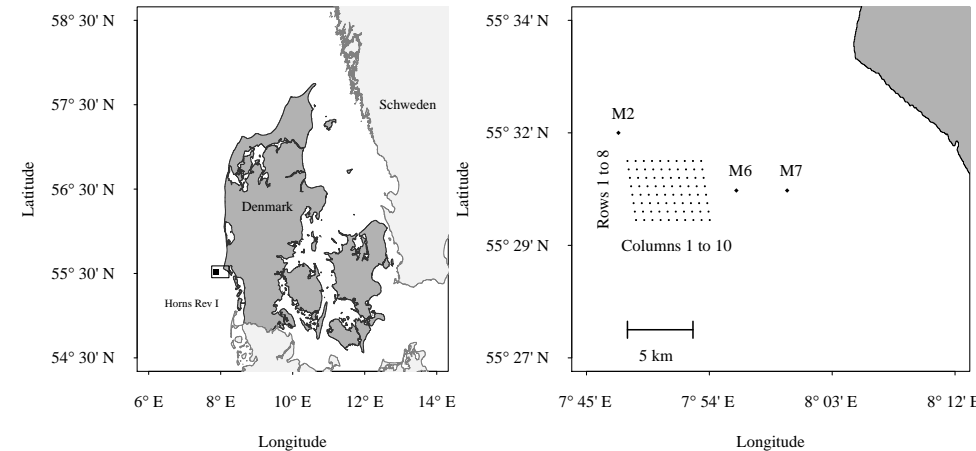
Using (2) we can obtain  $U_s$  from the thrust equation:

$$\frac{1}{2}\rho C_t A_0 U_0^2 = W \rho \int_0^{z_{\max}} U_0(U_0 - U) dz \quad \left\{ \begin{array}{l} C_t \text{ is obtained from the thrust curve} \\ W \text{ is the width of the wake} \\ z_{\max} \text{ is the height of the domain} \end{array} \right.$$

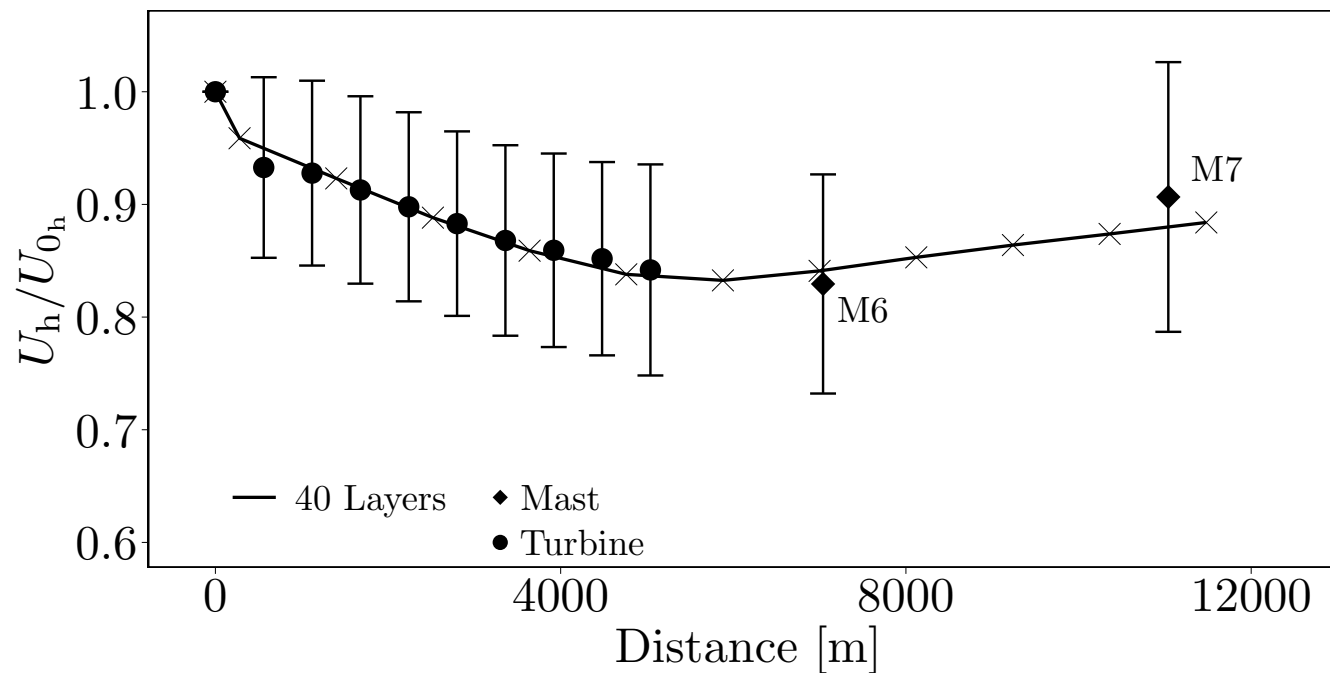
# Evaluation for Horns Rev I (80 × 2MW)

Model resolution:  $\Delta x = 1.12 \text{ km}$

	$\bar{U} \text{ (m/s)}$	$\theta \text{ (}^\circ\text{)}$
Obs:	$8 \pm 0.5$	$270 \pm 15$
Model:	8	270



Plot: Velocity deficit  $U_h/U_{0h}$  VS downstream distance (Volker et al. 2013)  
 $U_{0h}$  is the upstream and  $U_h$  the downstream hub wind velocity.



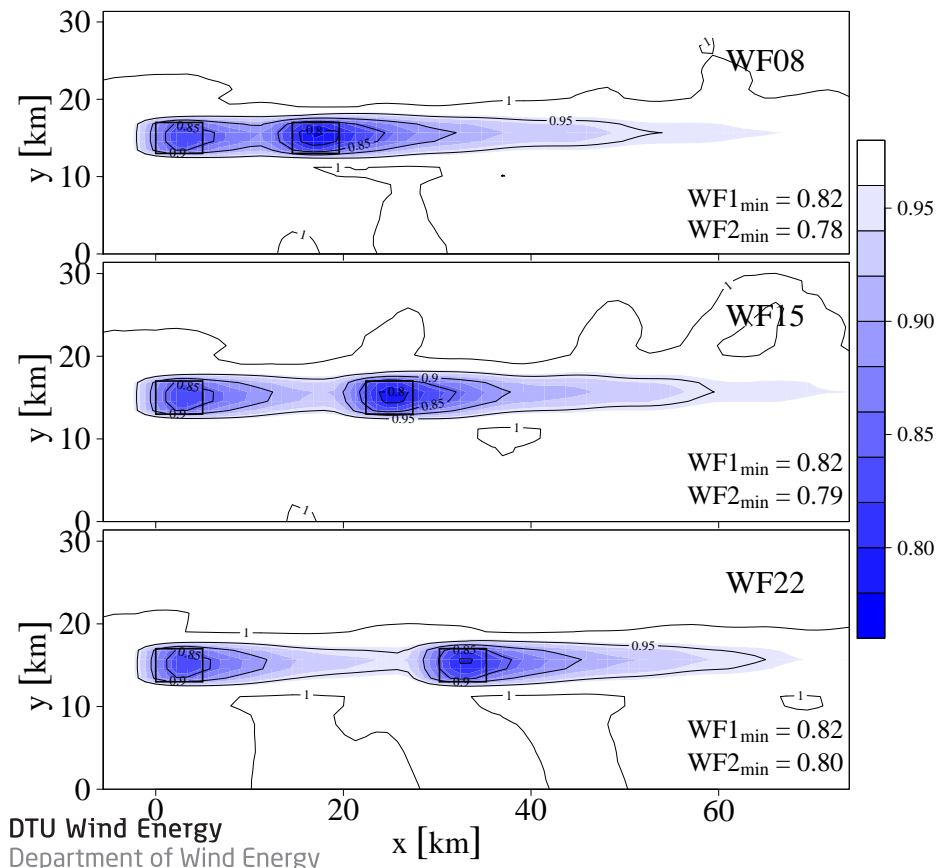
Volker, P. J., Badger, J., Hahmann, A. N., Ott, S. Implementation and evaluation of a wind farm parametrisation in a mesoscale model. To be submitted.

# Wind Farm Interaction - and idealised case study

Horizontal resolution  $\Delta x = 1.12$  km.  $\bar{U} = 8\text{m/s}$  and  $\theta = 270^\circ$ . WF size  $80 \times 2\text{MW}$

Run	WF Separation (km)	$P_{down}/P_{up}$
WF08	$8 \times 1.12$	0.80
WF15	$15 \times 1.12$	0.86
WF22	$22 \times 1.12$	0.91

Velocity Deficit:  $U/U_0$



Power Production:  $P = \frac{1}{2} \rho C_P \pi R_0^2 U_0^3$

